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Biomass Reference Points for Eastern Component Pollock (4VW+4Xmn)

Points de référence de la biomasse de la goberge de la composante Est (4VW + 4Xmn)

Heath H. Stone

Fisheries and Oceans Canada / Pêches et Océans Canada
St. Andrews Biological Station / Station biologique de St. Andrews
531 Brandy Cove Road / 531, rue Brandy Cove
St. Andrews
New Brunswick / Nouveau-Brunswick
Canada E5B 2L9

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ABSTRACT

A conservation Limit Reference Point (LRP) and Upper Stock Reference (USR) were calculated for Eastern Component (4VW+4Xmn) pollock based on a proxy for Bmsy using data from the Department of Fisheries and Oceans summer research vessel survey time series (1970-2011). For the purpose of calculating reference points, it was assumed that productivity of this resource has not changed appreciably over the past four decades. A 10-year period from 1984-1993 was arbitrarily chosen to reflect a sustained period of high productivity. The bias adjusted geometric mean total biomass for this period (a proxy for Bmsy) was 50,200 t with a 95% Confidence Interval (CI) ranging from 36,700 t to 72,600 t. The LRP (40% Bmsy proxy) was calculated as 20,100 t (95% CI: 14,674 to 29,043 t) and the USR (80% Bmsy proxy) as 40,100 t (95% CI: 29,347 to 58,086 t). Total survey biomass has only been above the LRP five times since 1994, four of which have occurred since 2006, suggesting that the status of this resource is improving.

RÉSUMÉ

Un point de référence limite de conservation et un point de référence supérieur ont été calculés pour la goberge de la composante Est (4VW + 4Xmn) en fonction d'une valeur approximative de la B_{rms} basée sur des données provenant de la série chronologique (1970-2011) de relevés d'été du navire de recherche de Pêches et Océans Canada. Aux fins du calcul des points de référence, on a supposé que la productivité de cette ressource n'a sensiblement pas changé au cours des quatre dernières décennies. Une période de dix ans allant de 1984 à 1993 a été arbitrairement choisie pour refléter une période soutenue de productivité élevée. La biomasse totale moyenne géométrique rajustée pour éliminer tout biais de cette période (valeur approximative pour la B_{rms}) était de 50 200 t avec un intervalle de confiance de 95 % (de 36 700 à 72 600 t). Le point de référence limite (valeur approximative de la B_{rms} de 40 %) était de 20 100 t (intervalle de confiance de 95 %, de 14 674 à 29 043 t) et le point de référence supérieur (valeur approximative de la B_{rms} de 80 %) de 40 100 t (intervalle de confiance de 95 %, de 29 347 à 58 086 t). La biomasse totale de relevé a seulement été plus élevée que le point de référence limite cinq fois depuis 1994, dont quatre fois depuis 2006, laissant entendre que la situation de cette ressource s'améliore.

INTRODUCTION

In the Western Atlantic, pollock (*Pollachius virens*) are found from southwestern Greenland to Cape Hatteras, North Carolina. Important Canadian fisheries for pollock occur on the Scotian Shelf, eastern Georges Bank, and the Bay of Fundy using primarily otter trawl and gillnets, but also handlines and longlines. In the Maritimes Region, two management areas are in place for pollock within the Northwest Atlantic Fisheries Organization (NAFO) Division 4VWX5 management unit: 4VW and 4X5 (Canadian waters only).

A detailed evaluation of pollock stock structure in 2003 indicated that pollock in 4VWX5 are represented by two population components: a slower-growing Eastern Component including Divisions 4V and 4W, as well as Unit Areas 4Xm and 4Xn, and a faster-growing Western Component including 4Xopqrs and Canadian portions of Area 5 (Figure 1). The Western and Eastern Component areas are used for assessment purposes but they differ geographically from the Management Areas.

The pollock fishery in the Eastern Component has shown appreciable temporal changes in landings, area fished and dominant gear type. During the 1980s, landings from the Eastern Component exceeded those from the Western Component (Average $_{1980\text{-}1990}$ = 21,000 t and 16,500 t for east and west, respectively), but declined significantly in the 1990s, and in 2003 dropped to a record low of 243 t (Figure 2). Landings from the Eastern Component have increased since then, and in 2011 were 1433 t (compared to 3905 t for the Western Component in 2011). Much of the Eastern Component catch from the 1980s originated from unit areas 4Vn, 4Vs, 4Xm and 4Xn (Table 1) and was taken mainly by the Tonnage Class (TC) 4+ sector (>100' otter trawl vessels). Since 1993, 4VW has been closed to cod and haddock directed fishing, which has reduced pollock landings from the Eastern Component, with most catches now coming from 4Xn. Despite this reduction in fishing effort, there has been little indication of a significant increase in biomass until recently. Since 1993, mobile gear catches (mostly TC 1-3) have accounted for about 70% of landings and for fixed gear about 30%. The mobile gear sector has participated in a test fishery in 4VW beginning in 2007, which has resulted in an increase in catch of about 400 t/year for 2007-2010 (Table 1). In 2011, a quota fishery for 4VW was implemented with 259 t allocated to fixed gear and 641 t allocated to mobile gear.

Analytical assessments have been conducted for the Western Component in the past to provide management advice, and beginning in 2012, a Management Procedure with Harvest Control Rule will be used to provide catch limits (DFO 2011). Currently, no analytical assessment is available for the Eastern Component and, therefore, no time series for age 4+ population biomass (approximately equivalent to Spawning Stock Biomass [SSB]), recruitment, or fishing mortality, so the pollock resource in this geographic area has been monitored solely with survey indices. Fishery catch at age information currently is available from 1989-2010, and survey age-specific indices of abundance are available from 1970-2011.

In this Research Document, a method for determining Precautionary Approach biomass reference points for Eastern Component pollock is presented based on Department of Fisheries and Oceans (DFO) summer survey biomass indices. As such, the indicator developed from the survey data is categorized as "empirical" and is a proxy for Bmsy.

METHODS

DFO has conducted annual summer bottom trawl surveys of the Scotian Shelf/Bay of Fundy Region since 1970. The survey follows a stratified random sampling design with stratum boundaries generally based on depth contours. A time series of stratified total biomass for pollock in the Eastern Component (4VW+4Xmn) is available from 1970-2011 and was calculated using data from strata 440-466, 470-473, 475, 477, and 478 (Figure 3). The two primary vessels used for the summer survey program were the *A. T. Cameron* (1970-1982) and *Alfred Needler* (1983-2011). A comparative fishing experiment was conducted in the early 1980s to develop catch conversion factors between these vessels for several groundfish species; however, the data for pollock was considered to be unreliable (Fanning 1985). Therefore, no adjustments have been made to the time series of total biomass estimates for the Eastern Component.

A sustained period of high productivity (1984-1993) was arbitrarily chosen from the survey time series of stratified total pollock biomass for use in calculations of Bmsy. The geometric mean (GM) from this 10-year period was considered to be a primary indicator of a proxy for Bmsy. A non-parametric boot-strapping procedure (Efron and Tibshirani 1993) was applied to the 10-year biomass time series to calculate a bias-adjusted estimate of Bmsy, Standard Error (SE) and 95% Confidence Intervals (95% CI). For the Limit Reference Point (LRP), a proxy for the "LRP = 40% Bmsy" was calculated as 40% of the GM total pollock biomass from 1984-1993. Similarly, for the Upper Stock Reference (USR), a proxy for the "USR = 80% Bmsy" was calculated as 80% of the GM total pollock biomass from 1984-1993.

Evidence for a change in production regime was examined from distribution plots (5 or 7-year average) of survey weight (kg)/tow aggregated by 10 minute rectangles of latitude and longitude. Catch at age from the commercial fishery (1982-2010) and RV survey (1984-2011) were examined for temporal changes in age structure. Weight at age (WAA) and condition factor (Fulton's K; weight/length^3; fork length range: 30-65 cm) from survey data (1970-2011) were also examined for temporal changes. No removal reference has been calculated for this stock since information on fishing mortality is not available; however, total mortality (Z) was calculated from the RV survey for the Eastern Component as:

$$Z = \ln\left(\frac{Catch\ Age\ 4-6_{year\ y}}{Catch\ Age\ 5-7_{year\ y+1}}\right)$$

and the 3-year moving average examined for long-term trends.

RESULTS

PROXIES FOR B_{MSY}, LIMIT REFERENCE POINT AND UPPER STOCK REFERENCE

The summer survey index, while variable, showed a period of increasing biomass from the early 1970s to the late 1980s, a period of declining biomass through the 1990s, followed by a general increase in biomass from about 2004 onwards, reaching the highest level in the time series in 2011 (Figure 3). The sharp increase in 2011 is inconsistent with the gradual trend of increasing biomass in recent years and appears to be a year-effect. Strong year-effects are apparent throughout the time series (i.e., 1980, 1985, 1987 and 2011) and probably reflect the semi-

pelagic schooling behaviour of pollock and changes in availability arising from different depth distributions of pollock in the water column at the time of the survey. Estimates of high total biomass during these years are attributed to one or two large catches of pollock as reflected by the wide standard error bars (Figure 3).

The 10-year period from 1984-1993 was arbitrarily chosen to reflect a sustained period of high productivity. During this period, all surveys were conducted by the *Alfred Needler* eliminating the concern of a potential vessel effect on catches and calculated indices of abundance. The bias adjusted geometric mean total biomass for this period (a proxy for Bmsy) was 50,200 t (SE ± 9,500 t), with a 95% CI ranging from 36,700 t to 72,600 t (Table 2). An LRP (40% of Bmsy proxy) was calculated as 20,100 t (SE ± 3,800 t) with a 95% CI ranging from 14,700 t to 29,000 t and an USR (80% Bmsy proxy) was calculated as 40,100 t (SE ± 7,600 t) with a 95% CI ranging from 29,300 t to 58,100 t.

EVIDENCE FOR A CHANGE IN PRODUCTIVITY

There is evidence from the RV survey of an expansion in spatial distribution and an increase in relative abundance of pollock into NAFO Areas 4Vn, 4Vs and eastern 4W during the late 1980s and early 1990s (Figure 4). The areas of highest catches then shifted to the central and western Scotian Shelf/Bay of Fundy region from the mid-1990s to mid-2000s but may be expanding eastwards again in 4W. It is not clear if these spatial shifts in relative abundance are related to environmental conditions, high F in the 1980s and early 1990s, or both. While most of the biomass for the Eastern Component is currently in 4Xn and western 4W, there is evidence that pollock still occur in 4V, but survey catches are much lower at present compared to the late 1980s. The catch at age for the fishery and RV survey both exhibit a period of diminished numbers at age for older ages from 1995 to 2005 with some modest improvement in age structure since then (Figure 5). Although there may have been a shift in spatial distribution, the recent improvement in age structure suggests that overall productivity may be improving again for the Eastern Component.

Survey WAA declined during the 1970s and 1980s for older ages (4-6) but not so much for ages 2-3, and it has been stable or increasing slightly for all ages since the mid-1990s (Figure 6, upper panel). Fulton's K also declined through the1980s but appears to have stabilized at lower level since the mid-1990s (Figure 6, lower panel). Noteworthy is that the decline for both WAA and condition factor occurred during a 10-year period of high biomass (1984-1993) used as proxy for Bmsy. Part of this decline may be attributed to colder temperatures on the eastern Scotian Shelf, which prevailed during the early 1990s.

Total mortality (Z) calculated from the RV survey for the Eastern Component increased from the early 1990s to the mid-2000s despite reductions in F since 1993 when the eastern Scotian Shelf was closed (Figure 7). Reasons for the increased Z during this period are not clear but could reflect higher natural mortality due to predation or changes in environmental conditions leading to poorer survival. Since 2005, there appears to have been a reduction in Z suggesting that that the situation may be improving. In any case, it is difficult to determine if there has been a change in productivity in Eastern Component pollock. For the purpose of calculating reference points, it is assumed that productivity of this resource has not changed appreciably over the past four decades.

CONCLUSIONS

A conservation Limit Reference Point and Upper Stock Reference were calculated for Eastern Component pollock based on a proxy for Bmsy using data from the DFO summer survey series. The LRP (40% Bmsy proxy) was calculated as 20,100 t and the USR (80% Bmsy proxy) as 40,100 t (Figure 8). Total survey biomass has only been above the LRP five times since 1994, four of which have occurred since 2006 (Figure 8) suggesting that the status of this resource is improving.

Future research should focus on the development of a Harvest Control Rule for the Eastern Component based on results from ongoing monitoring (i.e., annual summer RV survey) as well as reducing the variability in the summer survey series (i.e., by increasing the number of sets).

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Table 1. Annual pollock landings (t) from the Eastern Component by statistical area, 1982-2011.

	4Vn	4Vs	4Vu	4Wd	4We	4Wf	4Wg	4Wh	4Wj	4Wk	4Wl	4Wm	4Wu	4Xm	4Xn	Total
1982	149	2216	162	4	89	8	230	904	3181	1987	2469	25	69	4341	3154	18987
1983	104	5214	13	7	189	24	621	1577	235	1725	702	7	191	2713	2532	15855
1984	351	4598	101	5	60	9	207	1699	252	2061	1406		106	2251	3805	16912
1985	839	9375	7	79	80	6	1002	198	32	1156	247		43	4803	3014	20882
1986	1379	11639	138	202	30	2	658	289	454	986	239		220	4124	2448	22808
1987	915	9680	303	70	26	0	416	92	659	2302	29		154	4947	5987	25583
1988	1448	9307	224	128	85	10	746	124	44	934	841		165	5020	2599	21674
1989	4465	7542		253	79	30	313	253	272	1394	931	6	309	4239	5689	25774
1990	2124	6065		90	20	80	769	160	300	1172	1093	46	350	3078	3886	19233
1991	1043	3009		193	42	7	2146	132	477	1329	2229	106	72	2824	5172	18779
1992	284	2129		149	98	13	990	101	162	1064	2695	44	387	1594	5357	15066
1993	86	743		81	470	1	114	6	5	588	272	1	63	739	2563	5731
1994	437	329		19	434	0	69	11	4	787	60		6	878	1128	4161
1995	397	665		36	3	0	108	31	1	130	188	6	135	220	592	2513
1996	30	432		35	0	0	19	44	0	747	67	1	81	305	898	2660
1997	10	135		7	1	0	1	94	0	606	66	1	73	305	770	2071
1998	155	171		11	16	0	36	63	2	149	1160	1	20	257	1767	3806
1999	29	422		0	0		80	61	1	1067	248	0	3	247	803	2963
2000	6	234		0	0		20	2	0	145	85	0	7	153	239	891
2001	0	94		0	0		7	2	0	128	151	2	15	146	336	882
2002	0	39			0		0	2	0	37	39	0	1	77	317	513
2003	0	4		0	0		1	5	0	15	37	0	4	24	152	243
2004	0	9						2	0	25	135		1	25	144	340
2005	8	4			0		0	1	0	81	75		7	44	379	599
2006	0	15	0	0			0	5	0	67	98		0	42	269	496
2007	0	3	1			10	0	0	1	462	234		8	67	333	1120
2008	0	0					0	5		317	192		5	55	458	1032
2009	2	1			0			2	1	80	106	0	18	85	1059	1354
2010	0	5			0	0	0	2	0	127	413	0	2	36	505	1091
2011	0	35					0	6	4	35	202	0	1	17	1129	1433

Table 2. Boot-strapped bias adjusted estimates (500 replicates) and summary statistics for Bmsy, LRP and USR based on a 10-year time period (1984-1993) from the summer RV survey when pollock biomass was high.

Indicator	Point estimate (t)	Bias adj. estimate (t)	Std. error (t)	CV (%)	95% CI lower (t)	95% CI upper (t)
Bmsy	50768	50184	9482	18.46	36684	72608
LRP	20307	20074	3793	7.39	14674	29043
USR	40614	40147	7585	14.77	29347	58086

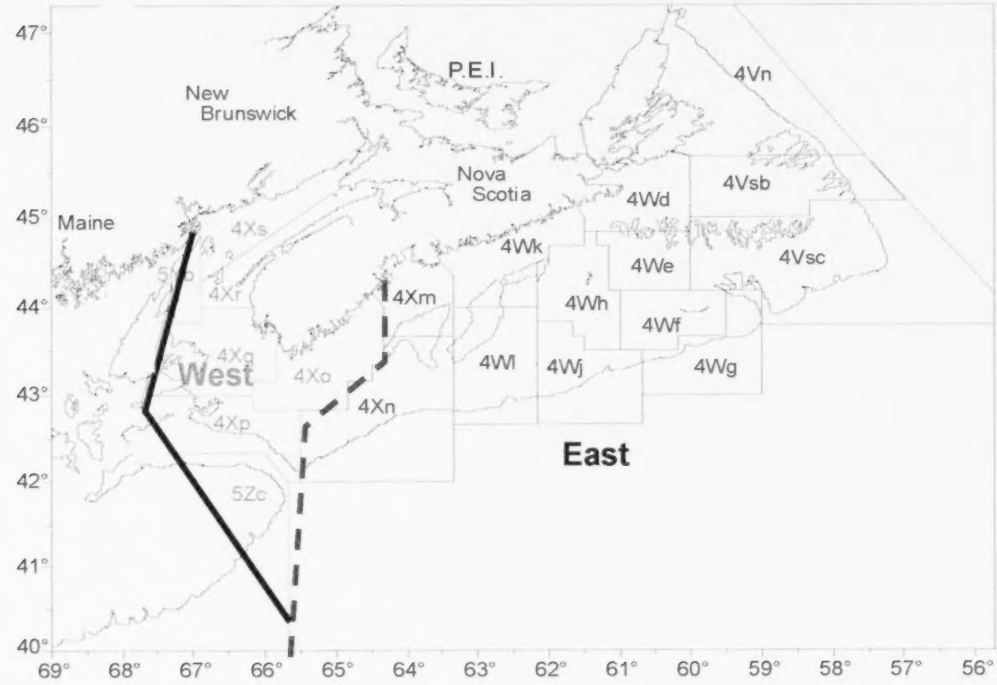

Figure 1. Canadian pollock management unit showing the Western (4Xopqrs5) and Eastern Component (4VW+4Xmn) areas. Dashed line separates Western and Eastern Components, solid line is the Canada/USA international boundary.

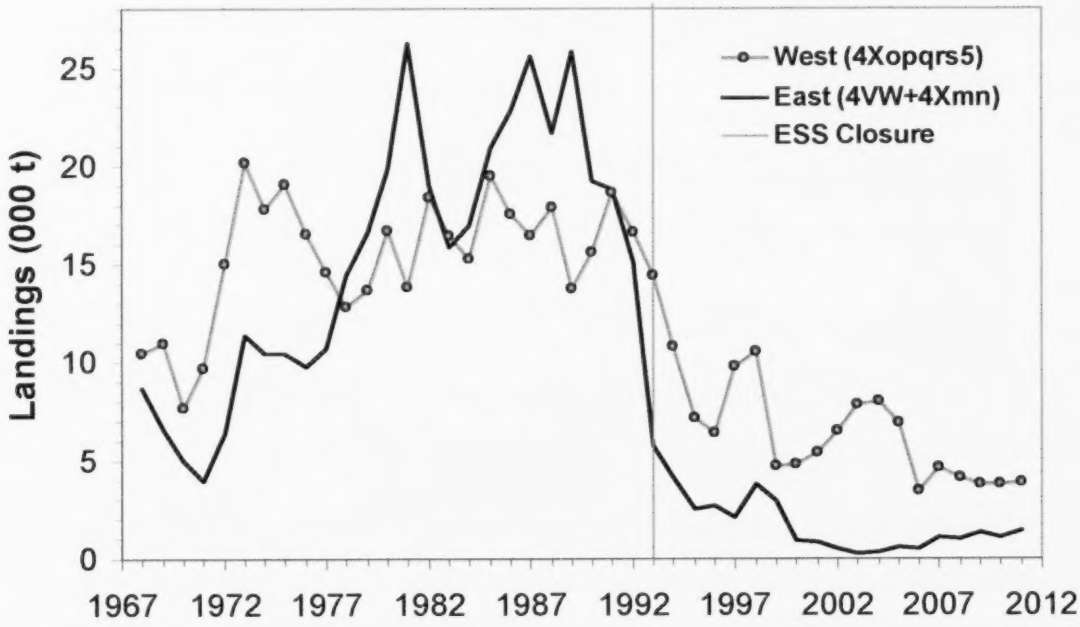

Figure 2. Pollock landings (000 t) from the Western (4Xopqrs5) and Eastern Component (4VW+4Xmn) areas, 1968-2011. Vertical line indicates the year of closure of the eastern Scotian Shelf (1993).

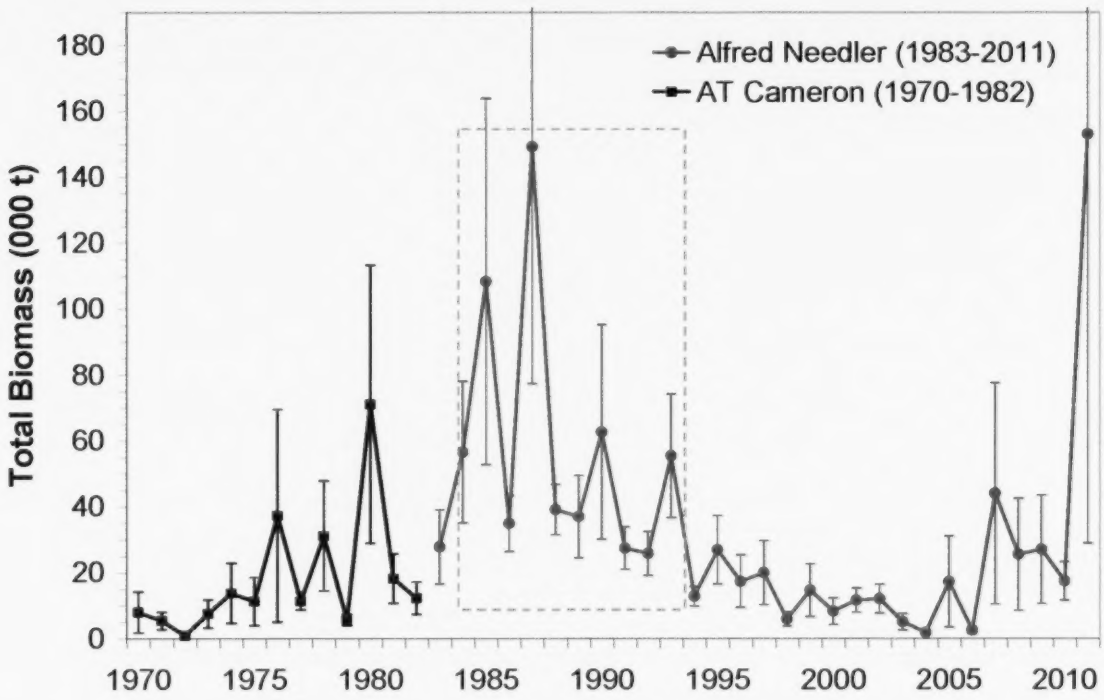

Figure 3. Stratified total biomass (000 t) of pollock in the Eastern Component (4VW+4Xmn) from the DFO summer research vessel surveys by the RV A.T. Cameron (1970-1982) and RV Alfred Needler (1983-2011). Strata representing the Eastern Component include: 440-466, 470-473, 475, 477, and 478. Vertical lines represent ± 1 Standard Error. The rectangle denotes a 10-year period from 1984-1993 when total biomass was high.

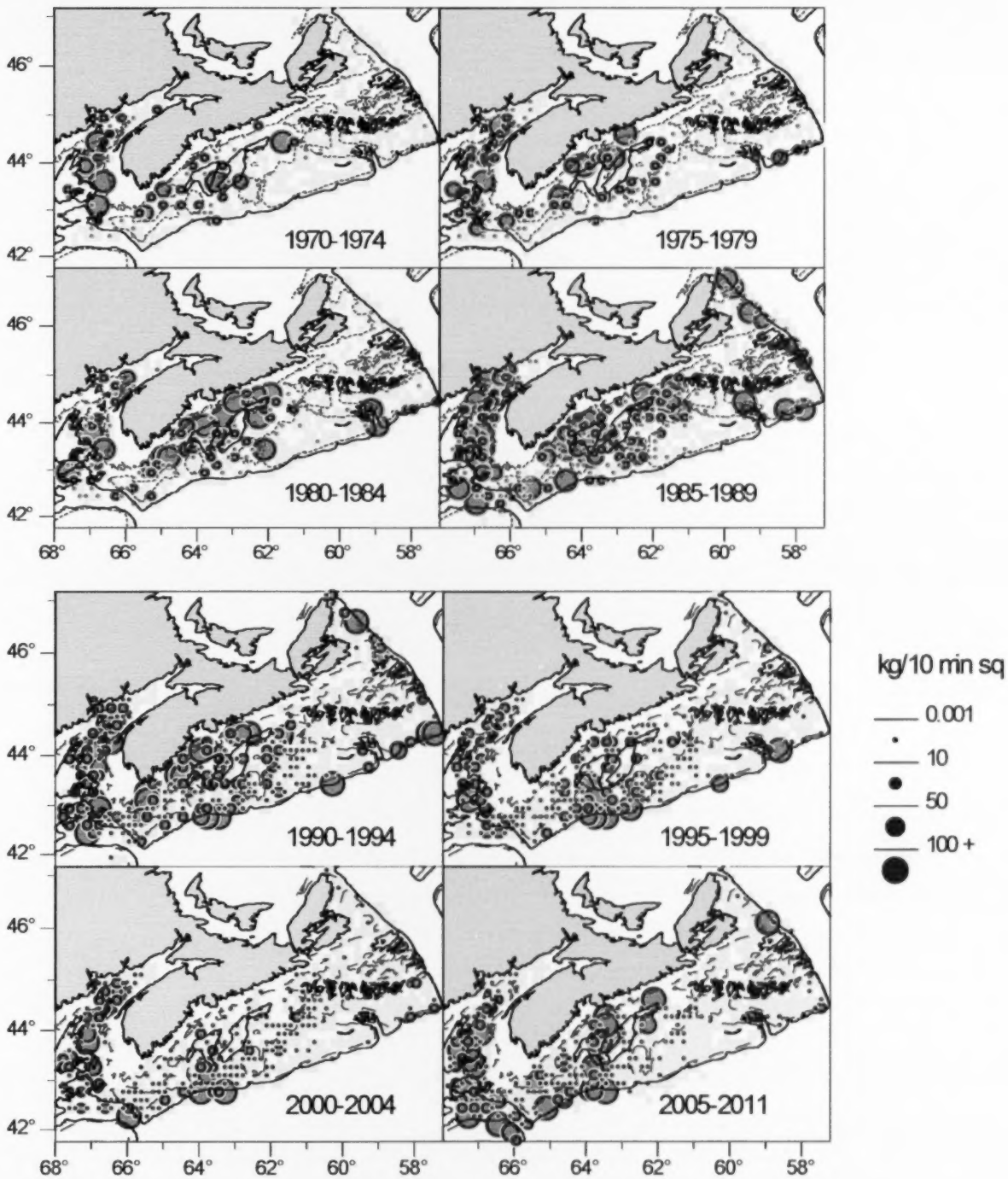

Figure 4. DFO summer survey biomass distribution (5 or 7-year mean weight (kg)/tow by 10 minute rectangles of latitude and longitude) for surveys conducted in the 1970s and 1980s (top panel), versus 1990s and 2000s (bottom panel). Grey shading indicates extent of area surveyed.

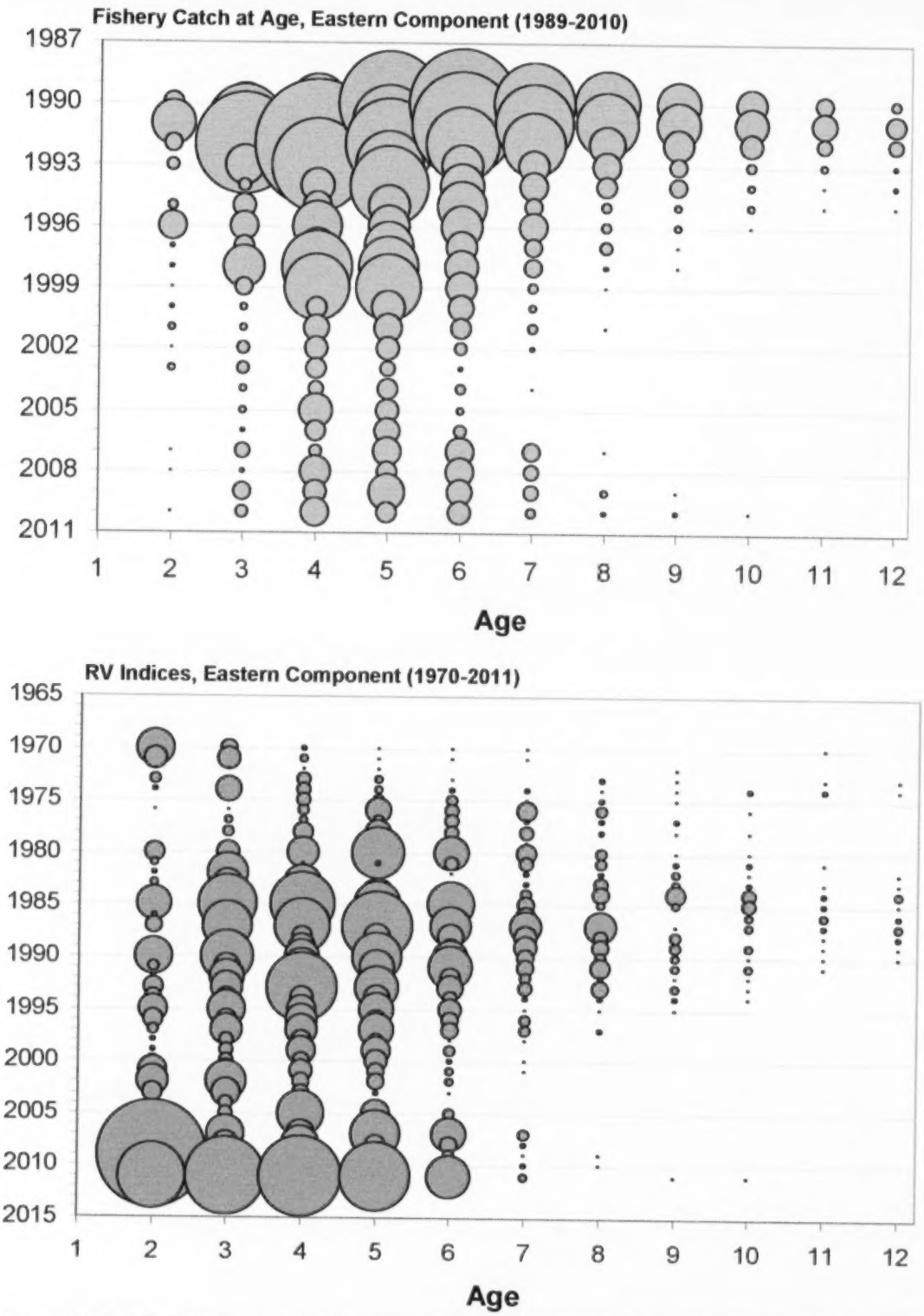

Figure 5. Fishery catch at age (1989-2010; upper panel)) and DFO summer survey indices of abundance (1970-2011; lower panel) for the Eastern Component. The area of the circle is proportional to the catch or index at that age and year.

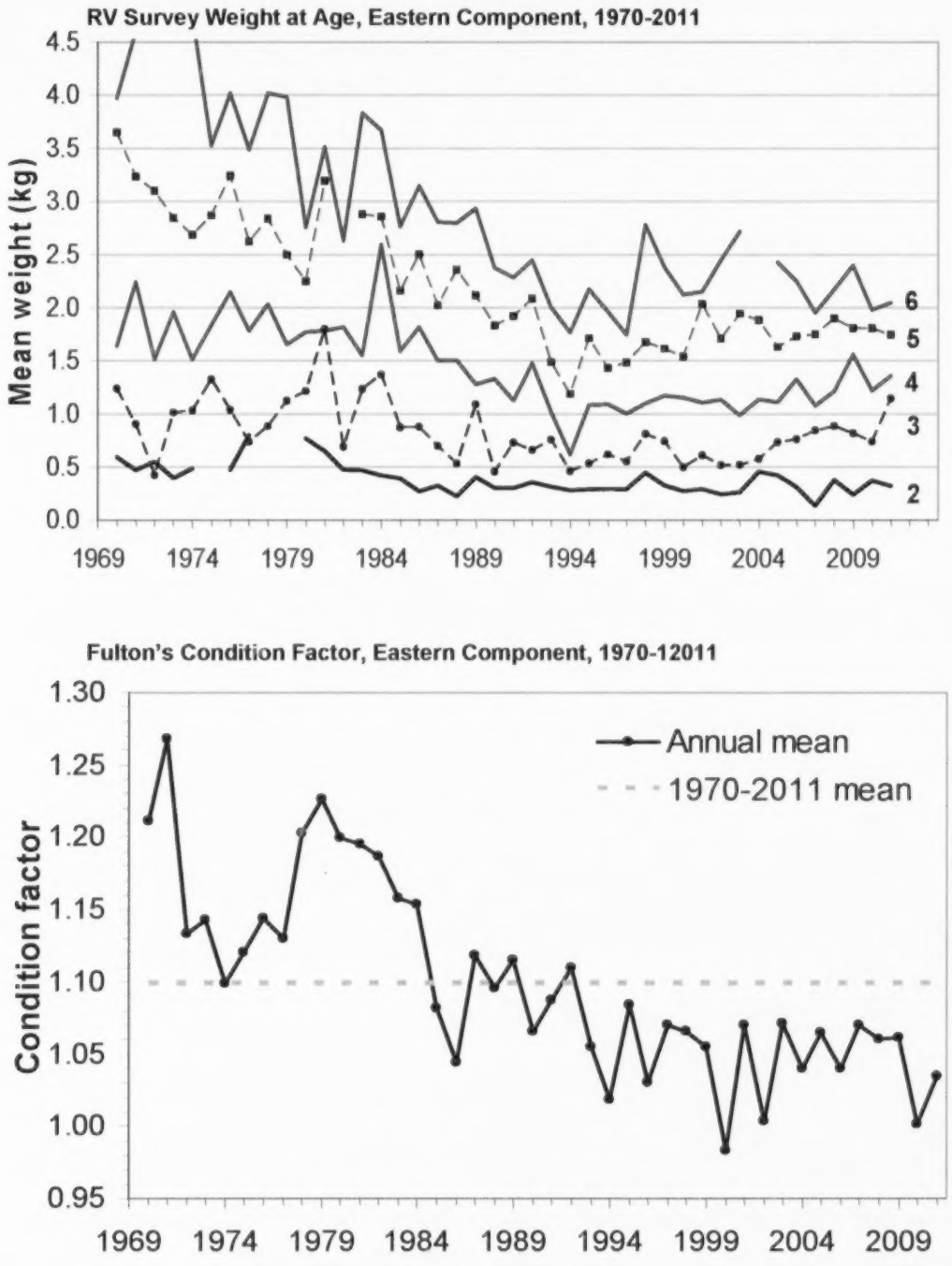

Figure 6. Mean weight at age (kg; upper panel) and Fulton's Condition factor (W/L^3, 35-60 cm FL; lower panel) for pollock in the Eastern Component based on DFO summer survey data from 1970-2011.

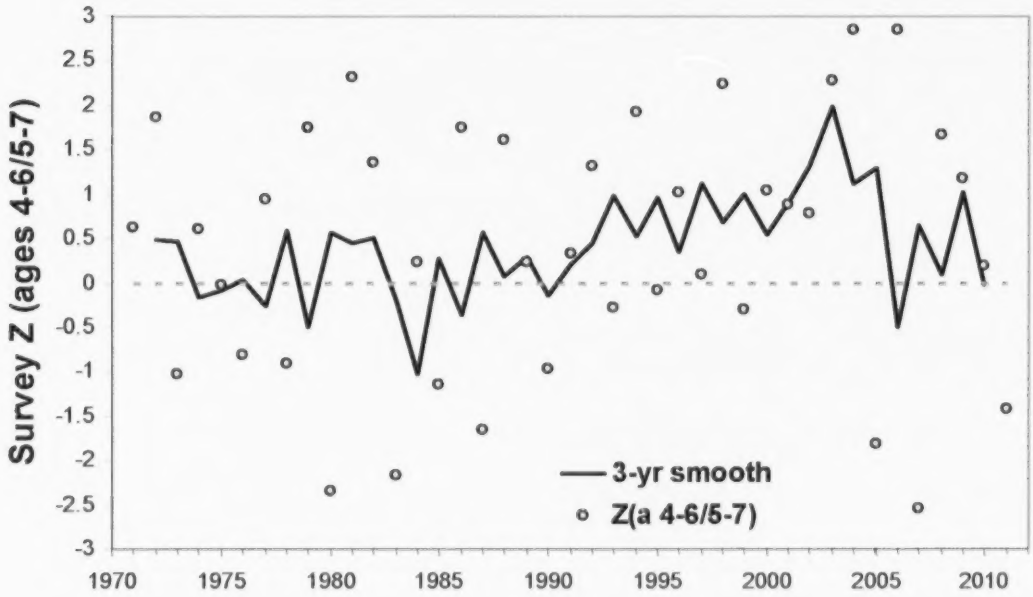

Figure 7. Smoothed (running 3-year average for ages 4-6/ages 5-7) estimates of total mortality for Eastern Component pollock from the summer RV survey, 1970-2011. Annual estimates of total mortality (unsmoothed) are shown as open circles.

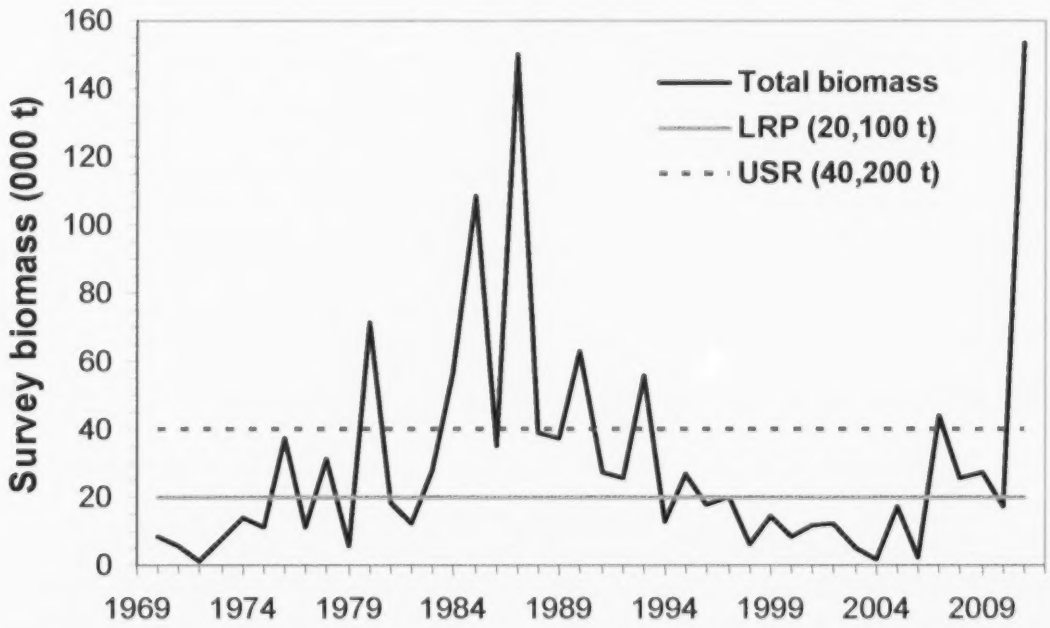

Figure 8. Stratified total biomass (000 t) of pollock in the Eastern Component (4VW+4Xmn) from the DFO summer research vessel surveys. Solid line: Limit Reference Point (20,100 t); Dashed Line: Upper Stock Reference (40,200 t).